(within past ~six months)

RECENT B PHYSICS RESULTS FROM THE TEVATRON

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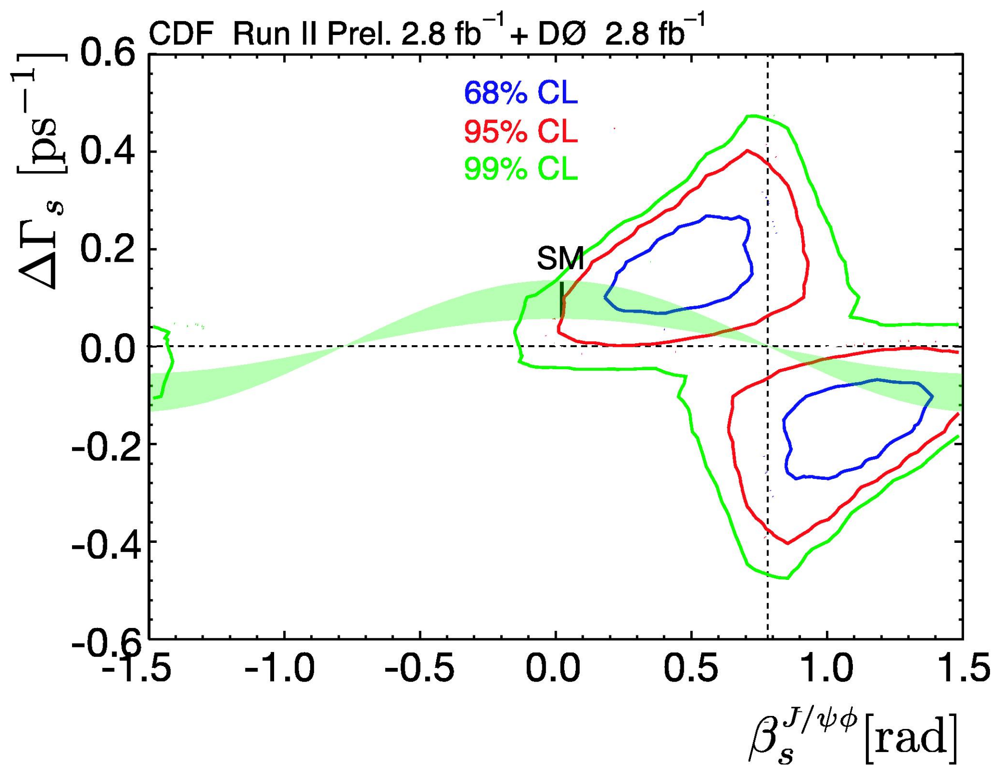
July 17, 2010

An interesting time for indirect NP searches…

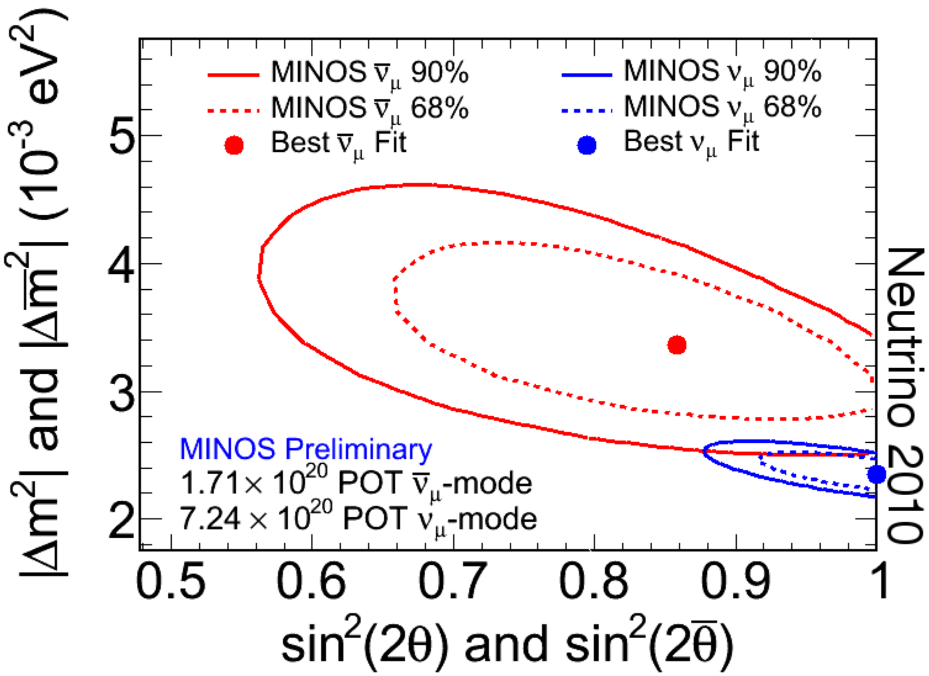
- Many interesting, though statistically limited, discrepancies observed recently
  - ~2σ deviation of CP phase β_s in $B_s^0 \to J/\psi\varphi$ decays observed by CDF, D0



http://tevbwg.fnal.gov/results/Summer2009_betas/

An interesting time for indirect NP searches…

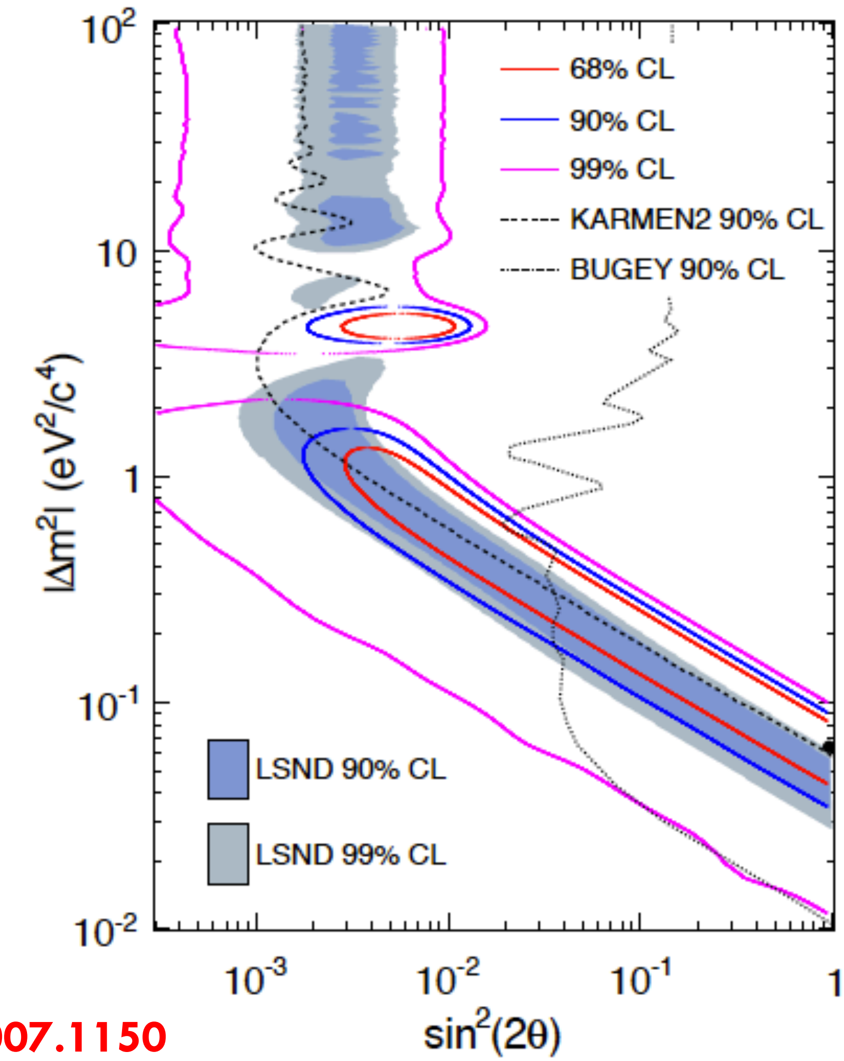
- Many interesting, though statistically limited, discrepancies observed recently
  - MINOS anti-ν_μ disappearance shows difference in Δm^2 w.r.t. ν_μ disappearance result



http://www-numi.fnal.gov/pr_plots/pr-nubar.pdf

An interesting time for indirect NP searches…

- Many interesting, though statistically limited, discrepancies observed recently
  - MiniBoone anti-ν_e result suggests agreement w/LSND sterile neutrino result



arXiV:1007.1150

An interesting time for indirect NP searches…

- Most notable example is new A_{sl}^{b} result from D0

In the News

Reports

- Fermilab Today – report on the wine and cheese seminar
- Fermilab Today – result of the week
- The New York Times, Dennis Overbye
- The New York Times editorial
- Chicago Tribune and graphic, Ron Grossman
- Science magazine – News of the Week, Adrian Cho
- Symmetry Breaking, Tona Kunz
- The Christian Science Monitor
- San Francisco Chronicle, Jon Carroll
- TIME magazine, Michael D. Lemonick
- Ira Flatow's Science Friday on NPR, guest: Ron Cowen, transcript
- Science News, Ron Cowen
- Scientific American, John Matson
- Discovery (tv) News, Jennifer Ouellette
- WRCT, Carnegie Mellon University's radio, (mp3)
- New Scientist, David Shiga
- BBC News, Paul Rincon
- The Times (UK), Mark Henderson
- Daily Telegraph (UK), Andrew Hough
- Der Spiegel (Germany)
- Die Zeit (Germany)
- Frankfurter Allgemeine Zeitung (Germany)
- SWR2 Campus (German radio)
- Neue Zürcher Zeitung (Switzerland), Christian Speicher
- Le Monde (France), Pierre Le Hir
- Science and Technology Facilities Council (UK), John Womersley
- Public Service (UK)

Press releases

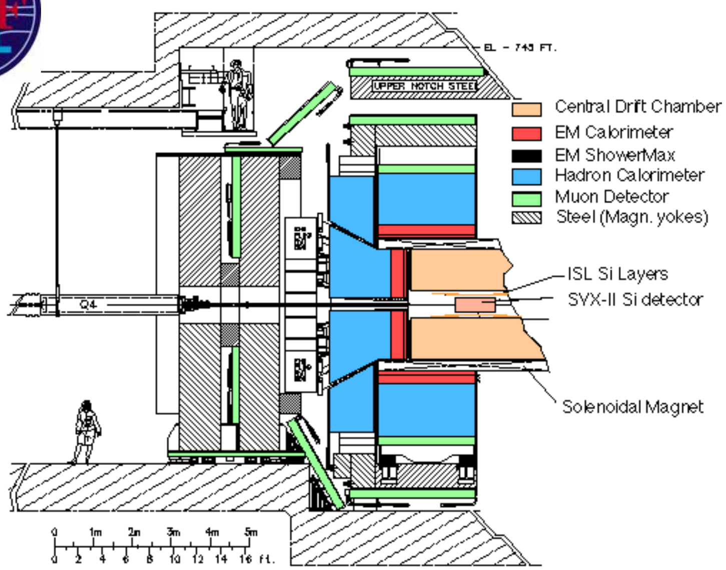
- Fermilab and images
- Symmetry Breaking
- Interactions.org
- Lancaster University
- University of Arizona
- Indiana University
- Centre de Physique des Particules de Marseille, (in French)
- York University
- SACLAY, (in French)
- UC Riverside
- IN2P3 Paris, (in French)
- Brookhaven National Lab
- UT Arlington
- SUNY Stony Brook

Blog Articles

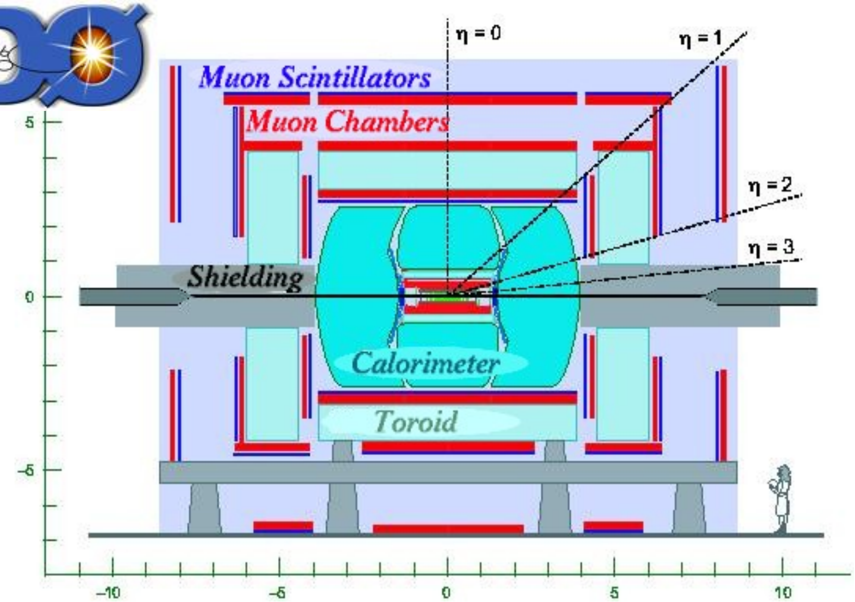
- Yale Alumni Magazine, Carole Bass. Our result was mentioned in President Bill Clinton's speech at Yale (video minute 9 onwards)
- Resonaances, Jester
- Resonaances, Jester
- The Reference Frame, Luboš Motl
- The Reference Frame, Luboš Motl
- The Reference Frame, Luboš Motl
- A Quantum Diaries Survivor, Tommaso Dorigo

See following talk by Derek Strom for details…

CDF and D0 detectors have different strengths detecting B hadrons



Strong tracking system, ability to trigger on displaced tracks
$\Rightarrow$ Good mass resolution, high statistics in non-leptonic decays



Excellent calorimetry, muon id, reverse direction of B field
$\Rightarrow$ Large samples of semi-leptonic and forward decays, good direct CPV res.

Di-muon triggers have dominated recent results
$\rightarrow$ comparatively easy to trigger, no lifetime bias

Start from generic likelihood…

- Almost all results presented use similar decays, MLL fit to measure quantities of interest

Flavor tagging decision and tagging power
Angular distribution of decay
Proper time and resolution
Invariant Mass

$$\mathcal{L} = f_s P_s(m \mid \sigma_m) P_s(t, \vec{\omega}, \vec{\xi} \mid \sigma_t, \vec{S}_D \vec{\mathcal{D}}) P_s(\sigma_t) P_s(\vec{\mathcal{D}})$$
$$+ (1 - f_s) P_b(m) P_b(t \mid \sigma_t) P_b(\vec{\omega}) P_b(\sigma_t) P_b(\vec{\mathcal{D}})$$

Account for differences between signal and background proper time resolution, flavor tagging

Decays

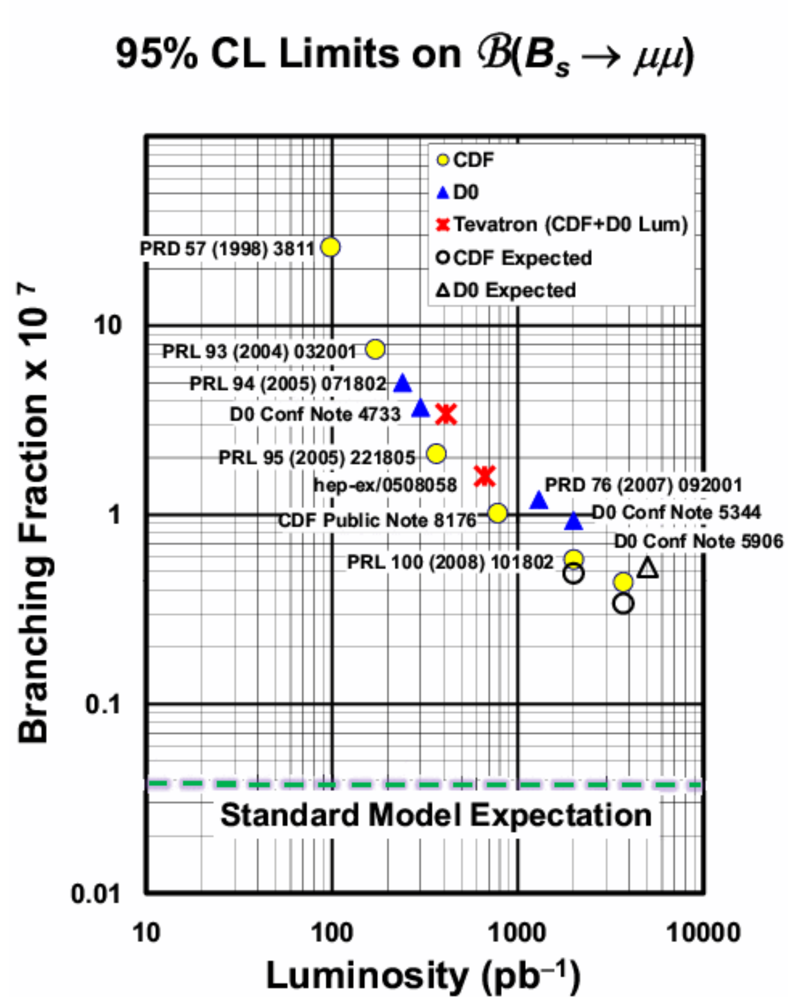
$$\mathcal{L} = f_s P_s(m \mid \sigma_m) P_s(t, \vec{\omega}, \vec{\xi} \mid \sigma_t, \vec{S}_D \vec{\mathcal{D}}) P_s(\sigma_t) P_s(\vec{\mathcal{D}})$$

$$+(1 - f_s) P_b(m) P_b(t \mid \sigma_t) P_b(\vec{\omega}) P_b(\sigma_t) P_b(\vec{\mathcal{D}})$$

Use rare decays to search for flavor changing neutral currents

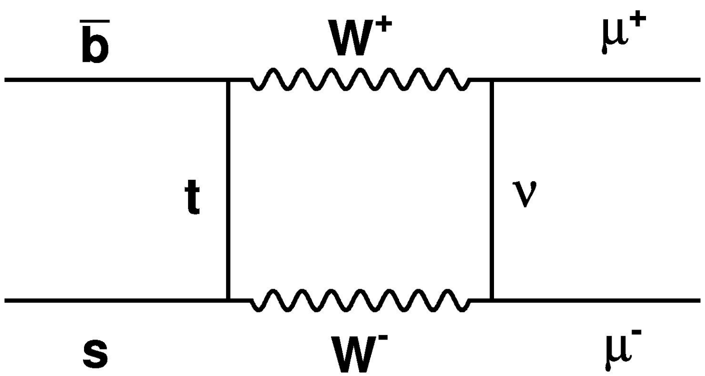
- Search for processes like
  - $B^0 \to \mu^+\mu^-$, $B_s^0 \to \mu^+\mu^-$
  - $D^0 \to \mu^+\mu^-$
  - $B^0, B_s^0 \to e^+\mu^-$

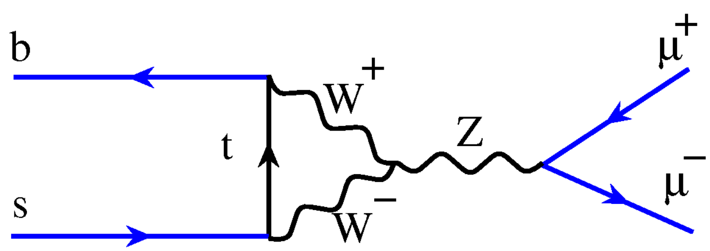
    $\Rightarrow$ leptoquarks
- SM processes are extremely rare or forbidden
  - $\mathcal{B}(B_s^0 \to \mu^+\mu^-) = (3.6 \pm 0.3) \times 10^{-9}$
- New physics (e.g. SUSY) predicts new sources of FCNC



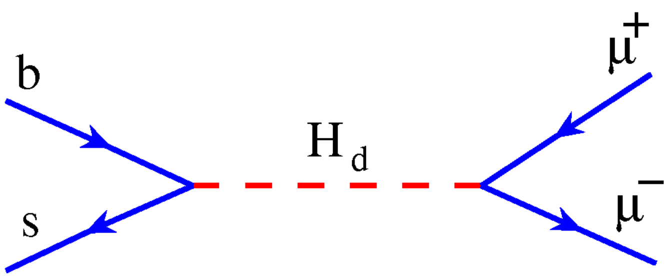
Examples of $B_s^0 \to \mu^+\mu^-$ Decay Processes

- SM processes





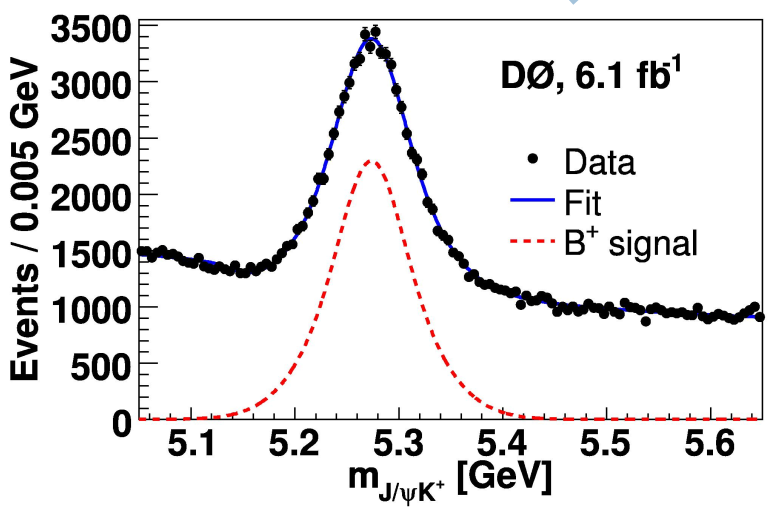
- New physics processes

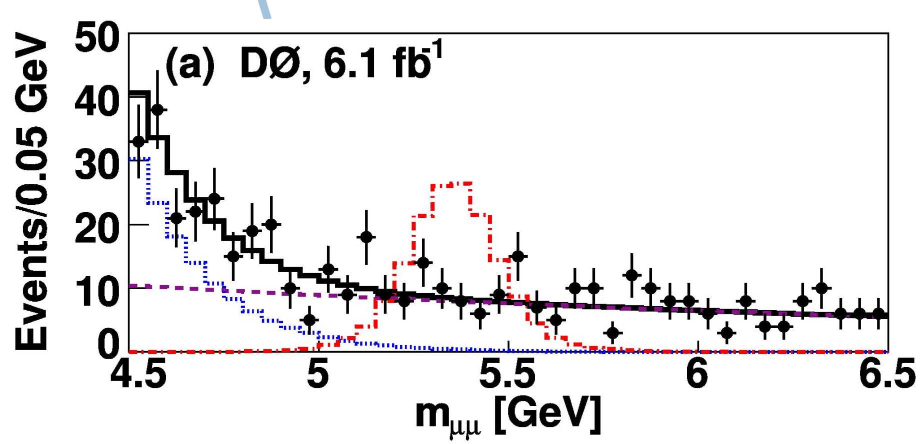


New limit on $\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)$

$$\mathcal{B}\left(B_s^0 \rightarrow \mu^+\mu^-\right) = \frac{N\left(B_s^0\right)}{N(B^+)} \cdot \frac{\epsilon_{B^+}}{\epsilon_{B_s^0}} \cdot \frac{f_u}{f_s} \cdot \mathcal{B}\left(B^+\right)$$

Uncertainty on production fraction contributes 15% uncertainty to measurement

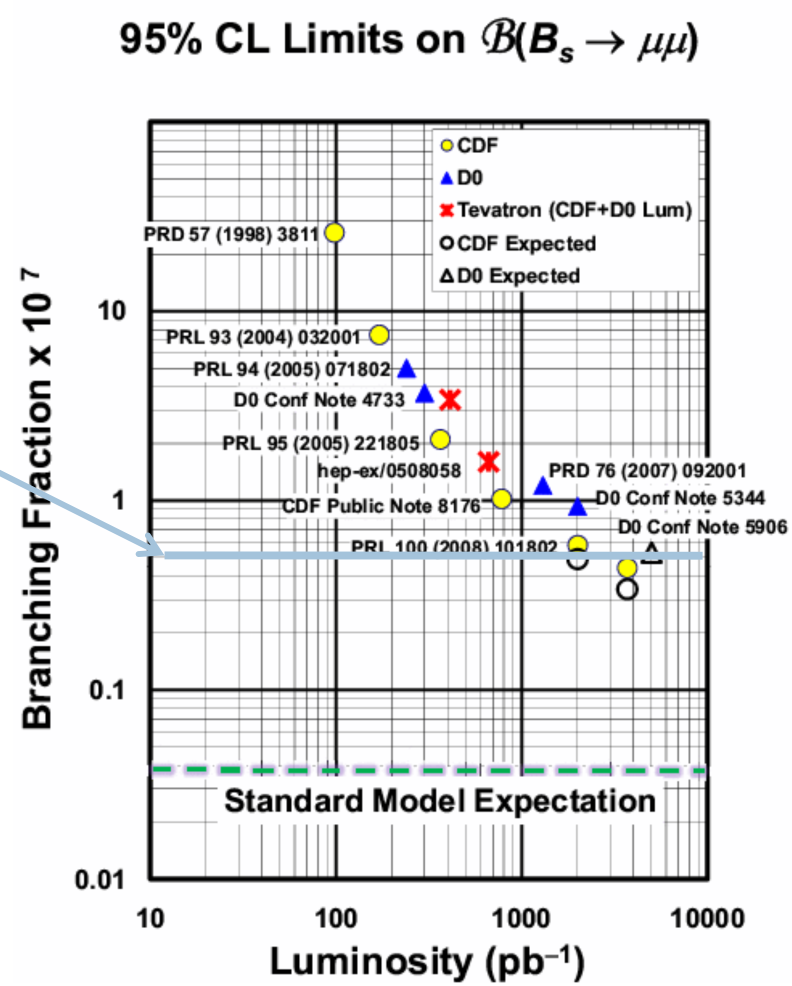




$B_s^0 \rightarrow \mu^+\mu^-$ Branching Ratio Approaching SM Predictions!

- $\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-)$ @ 95% CL
  - D0 ($6.1\ fb^{-1}$): $< 5.1\times10^{-8}$
  - CDF ($3.7\ fb^{-1}$): $< 4.3\times10^{-8}$

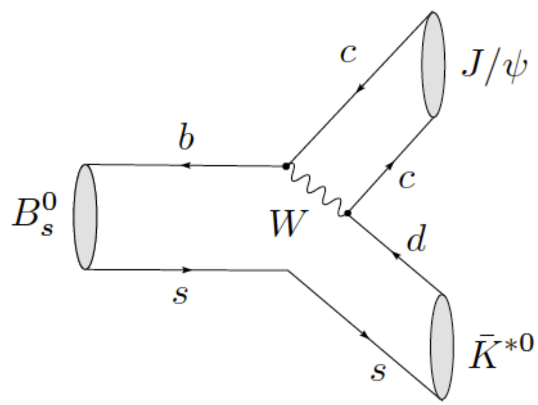
SM $\mathcal{B}(B_s^0 \rightarrow \mu^+\mu^-) = (3.6 \pm 0.3)\times10^{-9}$

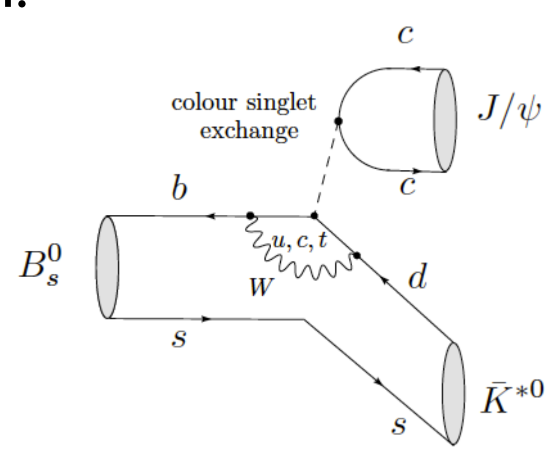


http://www-d0.fnal.gov/Run2Physics/WWW/results/final/B/B10B/

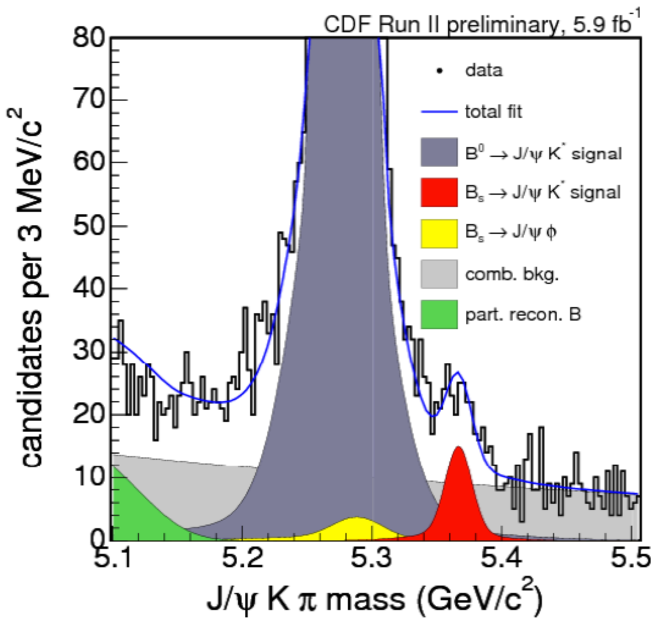
Study of $B_s^0 \to J/\psi K^{*0}$ and $B_s^0 \to J/\psi K_s^0$ decays

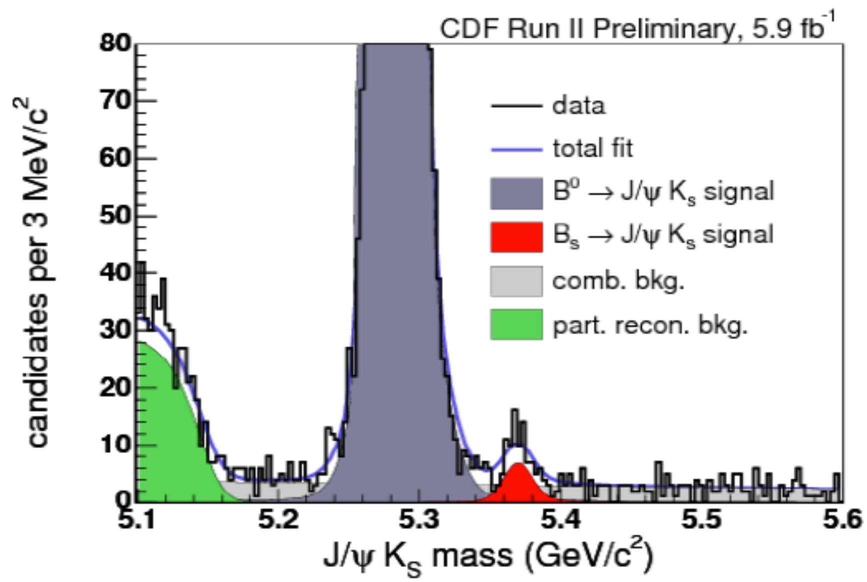
- Can use $B_s^0 \to J/\psi K^{*0}$ ($J/\psi K_s^0$) to study CP violation in B_s^0 system
  - $B_s^0 \to J/\psi K^{*0}$ helps to understand penguin contributions to CP violation in $B_s^0 \to J/\psi\varphi$ (PRD 79, 014005 (2009))
    - Need to understand penguins to "pin down" NP contributions
  - $B_s^0 \to J/\psi Ks^0$ can be used to measure $\tau_H(B_s^0)$, CKM γ
  - First need to observe them!





First Observation of $B_s^0 \to J/\psi K^{*0}$ and $B_s^0 \to J/\psi K_s^0$!





$N(B_s^0) = 151 \pm 25$, $N(B^0) = 9530 \pm 110$

8σ significance w.r.t. null hypothesis

$N(B_s^0) = 64 \pm 14$, $N(B^0) = 5954 \pm 79$

7.2σ significance w.r.t. null hypothesis

$$\mathcal{B}(B_s^0 \to J/\psi \bar{K}^{*0}) = (8.3 \pm 1.2\ (\mathrm{stat}) \pm 3.3\ (\mathrm{syst}) \pm 1.0\ (\mathrm{frag}) \pm 0.4\ (\mathrm{PDG})) \times 10^{-5}$$

$$\mathcal{B}(B_s^0 \to J/\psi \bar{K}_s^0) = (3.5 \pm 0.6\ (\mathrm{stat}) \pm 0.4\ (\mathrm{syst}) \pm 0.4\ (\mathrm{frag}) \pm 0.4\ (\mathrm{PDG})) \times 10^{-5}$$

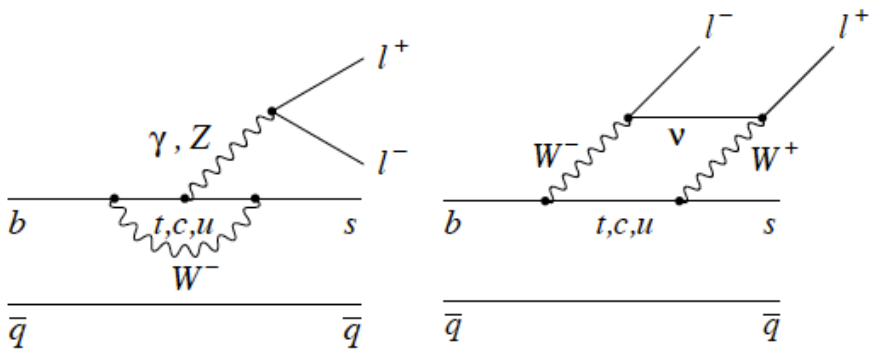
CDF has updated f_s/f_d (PRD77, 072003 (2008)) w/new $D_s^+ \to \varphi\pi^+$ BR: $f_s/f_d = 0.269 \pm 0.033$

Angular Analysis

$$\mathcal{L} = f_s P_s(m \mid \sigma_m) P_s(t, \vec{\omega}, \vec{\xi} \mid \sigma_t, \vec{S}_D \vec{\mathcal{D}}) P_s(\sigma_t) P_s(\vec{\mathcal{D}})$$

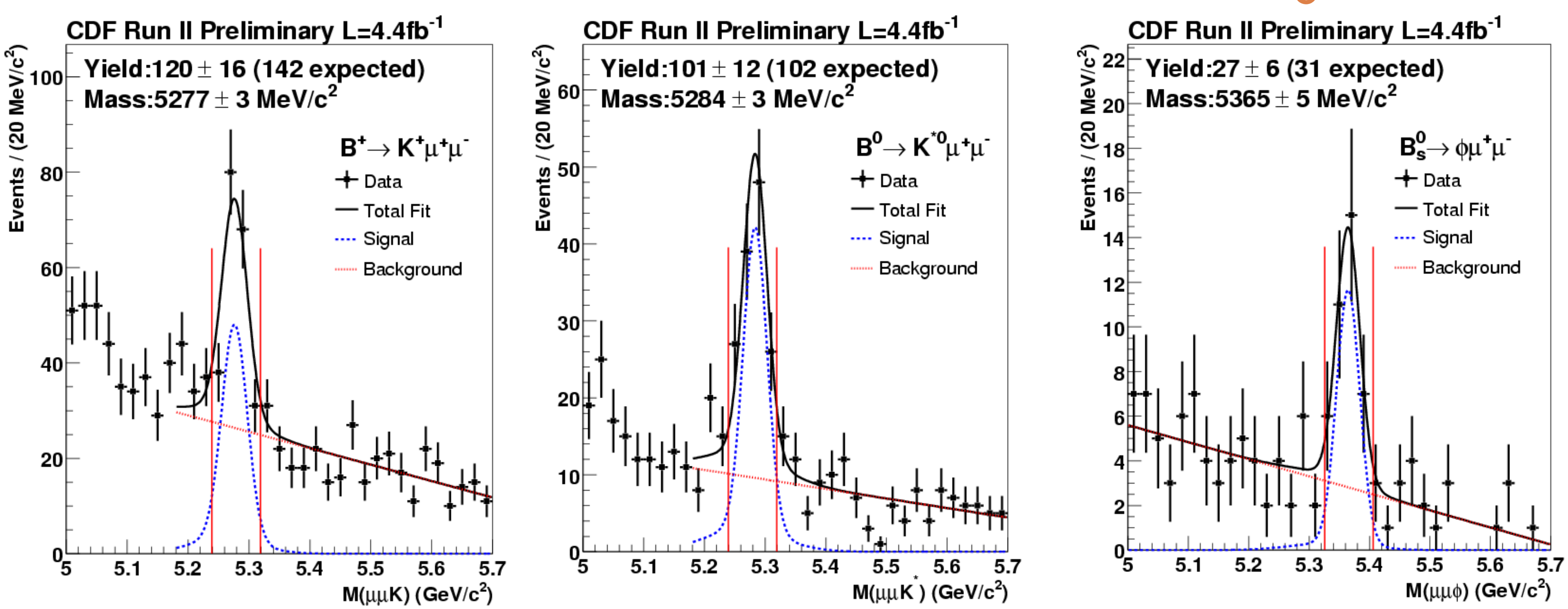
$$+ (1 - f_s) P_b(m) P_b(t \mid \sigma_t) P_b(\vec{\omega}) P_b(\sigma_t) P_b(\vec{\mathcal{D}})$$

FCNC studies of $b \to s\mu^+\mu^-$ decays



SM decays expected through EW penguin or box diagrams, as in $B_s^0 \to \mu\mu$

First observation, 6.3σ significance



http://www-cdf.fnal.gov/physics/new/bottom/091112.blessed-b2smumu_afb/index.html

$b \rightarrow s\mu^+\mu^-$ absolute and differential branching ratios

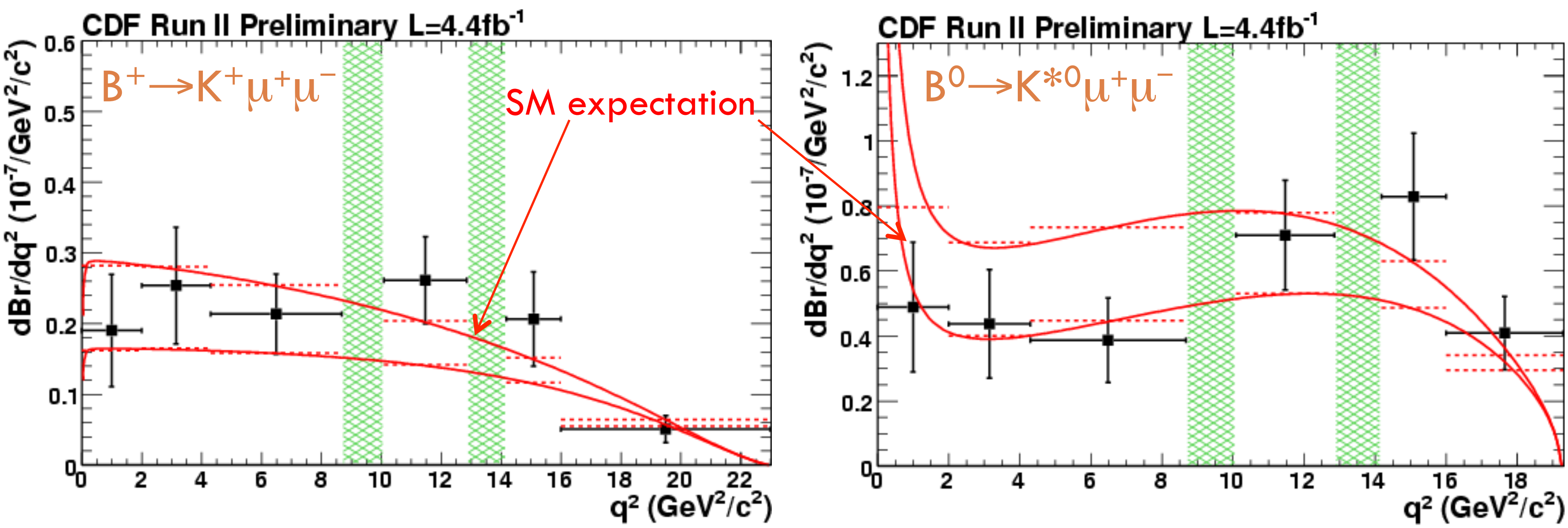
Measure $B \rightarrow h\mu^+\mu^-$ branching ratios relative to $B \rightarrow J/\psi h$ decays

$$\mathcal{B}(B^+ \to K^+\mu^+\mu^-) = [0.38 \pm 0.05(\text{stat}) \pm 0.03(\text{syst})] \times 10^{-6},$$

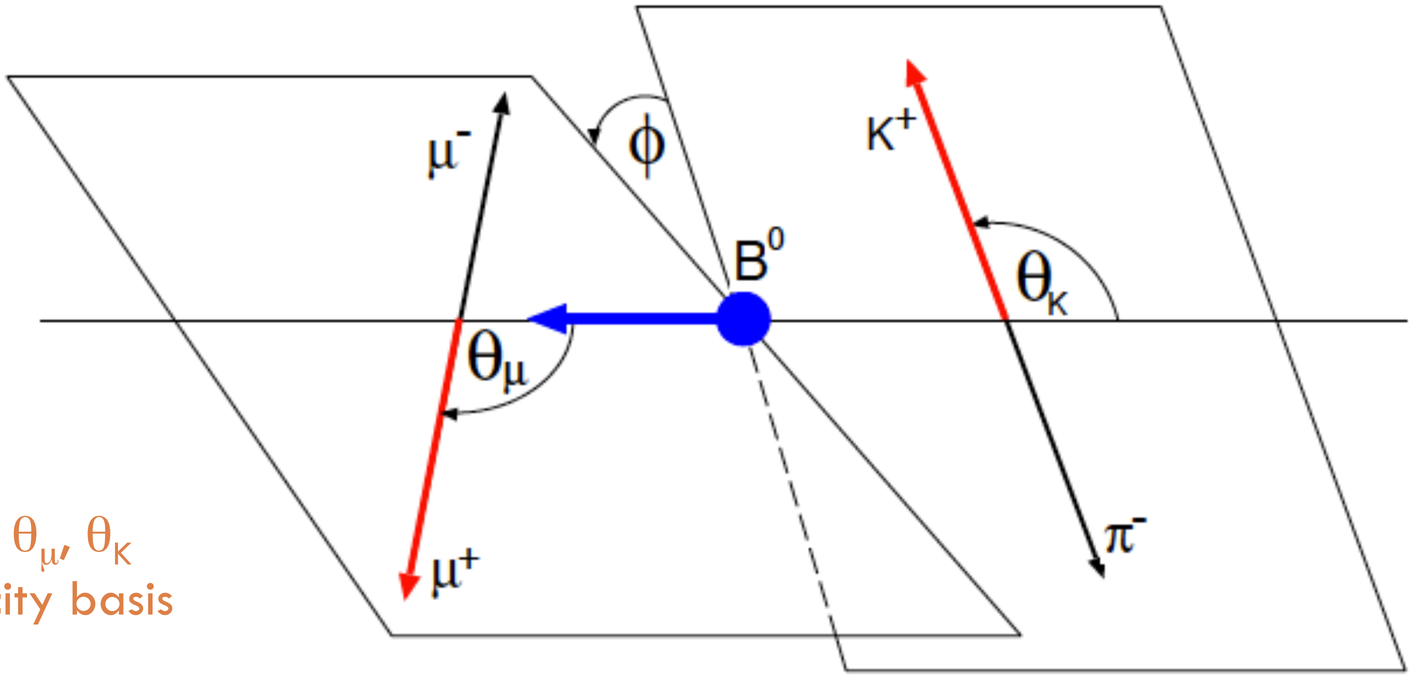
$$\mathcal{B}(B^0 \to K^{*0}\mu^+\mu^-) = [1.06 \pm 0.14(\text{stat}) \pm 0.09(\text{syst})] \times 10^{-6},$$

$$\mathcal{B}(B_s^0 \to \phi\mu^+\mu^-) = [1.44 \pm 0.33(\text{stat}) \pm 0.46(\text{syst})] \times 10^{-6}.$$

B^+, B^0 competitive w/BELLE measurements (PRL103, 171801)



$B \rightarrow K^{(*)}\mu^+\mu^-$ forward-backward asymmetry & polarization



Define θ_μ, θ_K in helicity basis

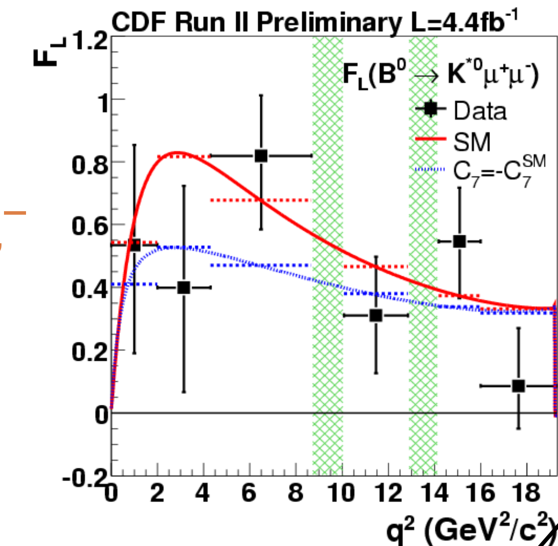
$$P_s(\cos\theta_K) \propto \frac{3}{2}F_L\cos^2\theta_K + \frac{3}{4}(1-F_L)(1-\cos^2\theta_K)$$

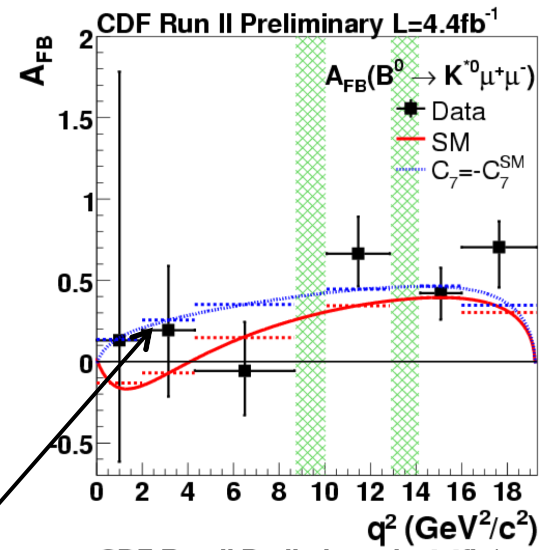
For B^+, set F_L=1

$$P_s(\cos\theta_\mu) \propto \frac{3}{4}F_L(1-\cos^2\theta_\mu) + \frac{3}{8}(1-F_L)(1+\cos^2\theta_\mu) + A_{FB}\cos\theta_\mu$$

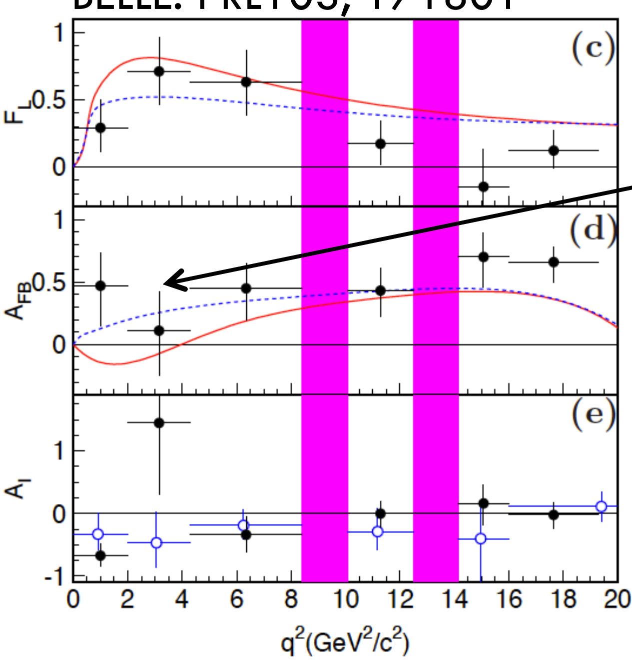
F_L and A_{FB} in $B \to K^{(*)}\mu^+\mu^-$

$B^0 \to K^{*0}\mu^+\mu^-$



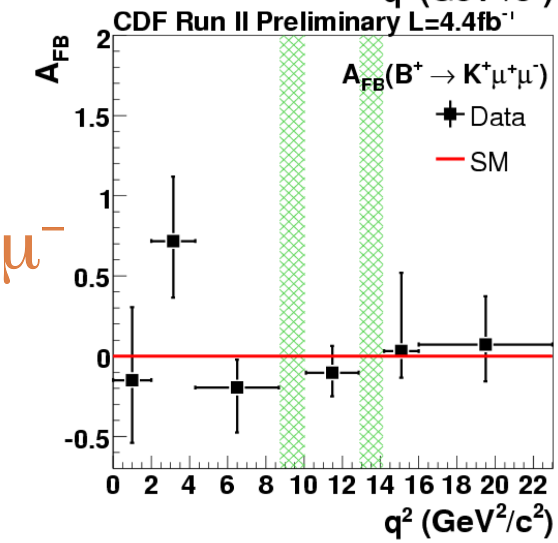


BELLE: PRL103, 171801



Excess in A_{FB} at low q^2

$B^+ \to K^+\mu^+\mu^-$

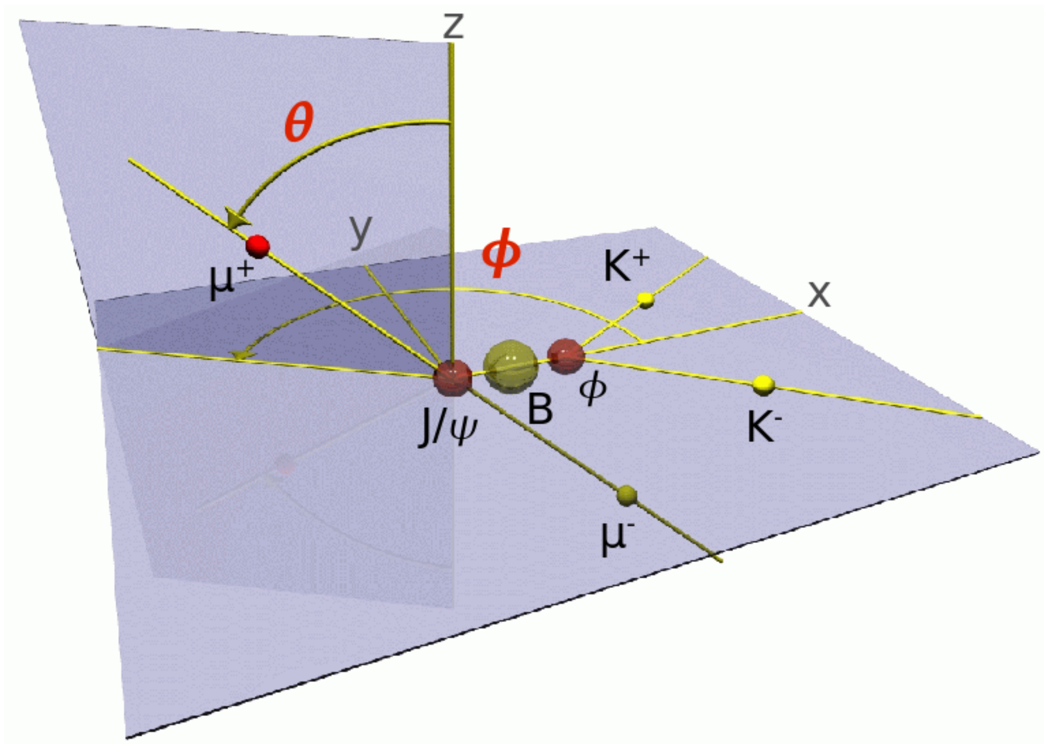


CP Violation in $B_s^0 \rightarrow J/\psi\varphi$

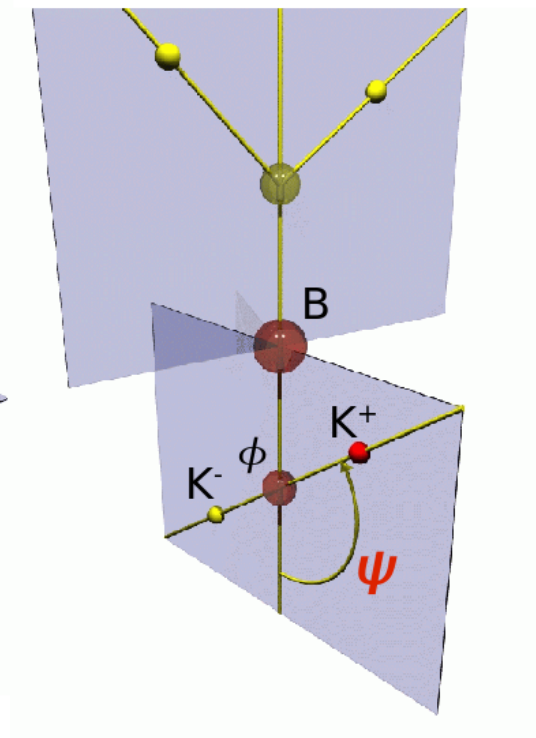
$$\mathcal{L} = f_s P_s(m \mid \sigma_m) P_s(t, \vec{\omega}, \vec{\xi} \mid \sigma_t, \vec{S}_D \vec{\mathcal{D}}) P_s(\sigma_t) P_s(\vec{\mathcal{D}})$$

$$+(1 - f_s) P_b(m) P_b(t \mid \sigma_t) P_b(\vec{\omega}) P_b(\sigma_t) P_b(\vec{\mathcal{D}})$$

Use transversity basis to separate CP even and CP odd states



J/ψ rest frame

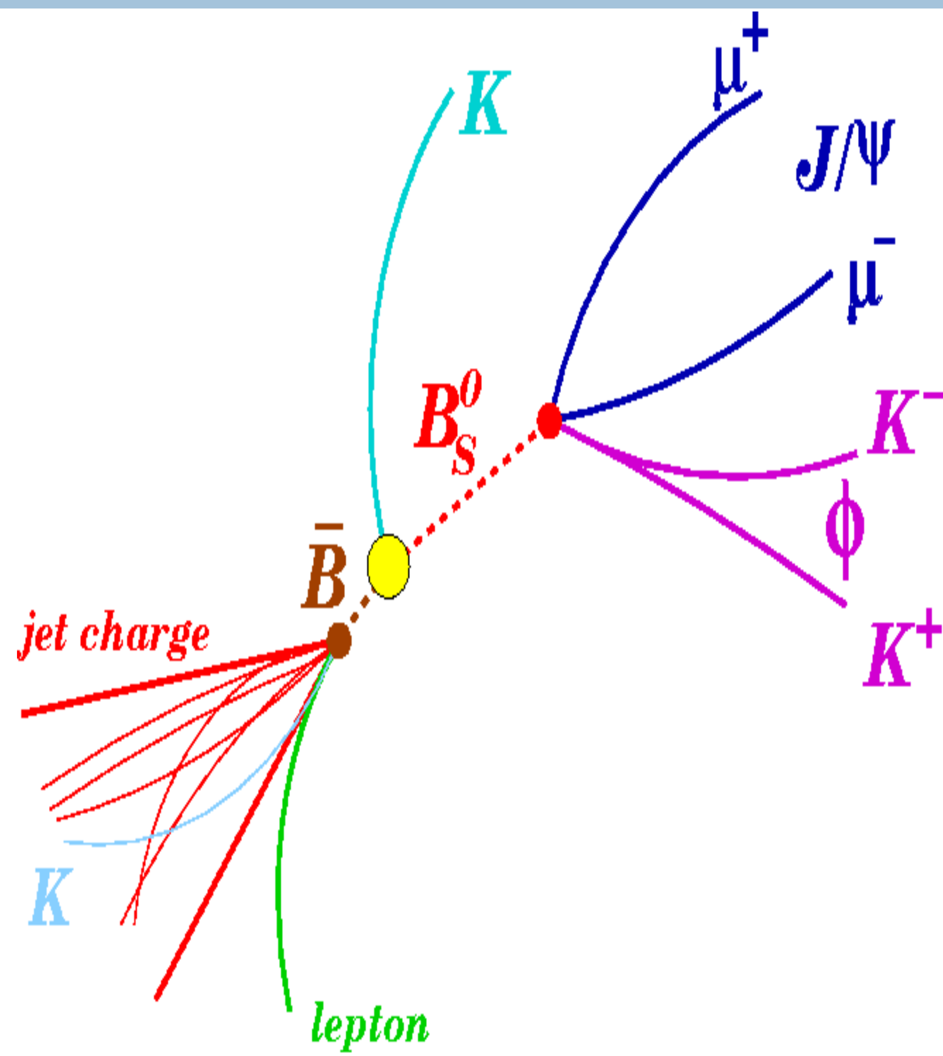


φ rest frame

VV final state defines 3D coordinate system

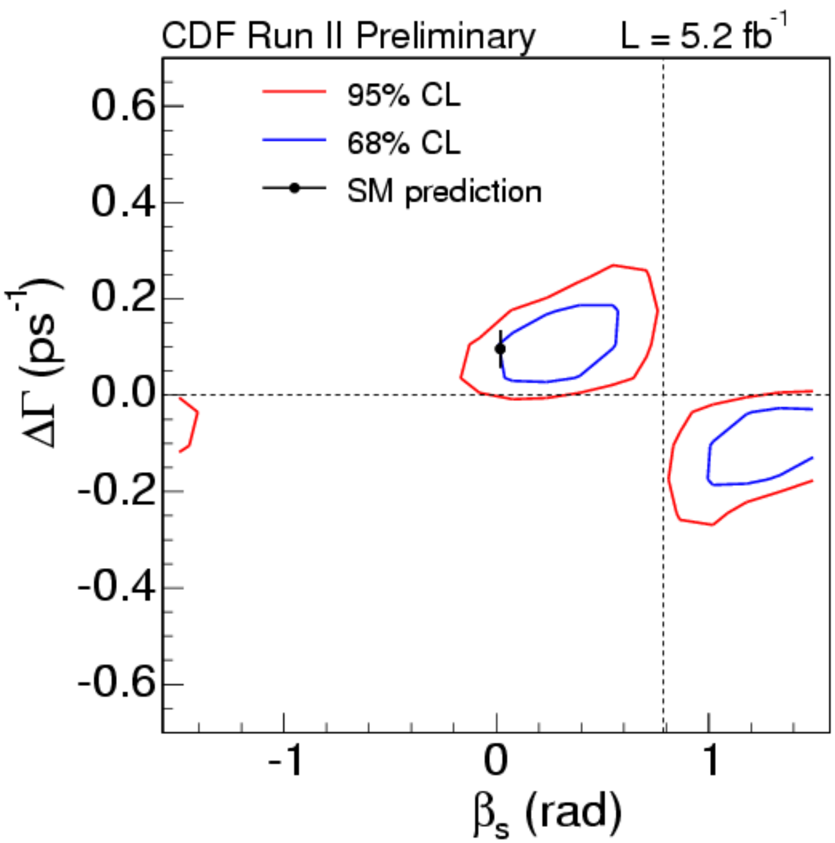
Need flavor tagging for best sensitivity to CP violation

- Define opposite side, same side tags
  - Can calibrate opposite side on B^+ decays (self-tagging)
  - Need to calibrate same side with B_s^0 decays
    - Use B_s^0 mixing measurement



CDF updates flavor-tagged $B_s^0 \to J/\psi\varphi$ result to 5 fb^{-1}

Fit includes possible non-zero S-wave component ($J/\psi f_0$, $J/\psi KK$)

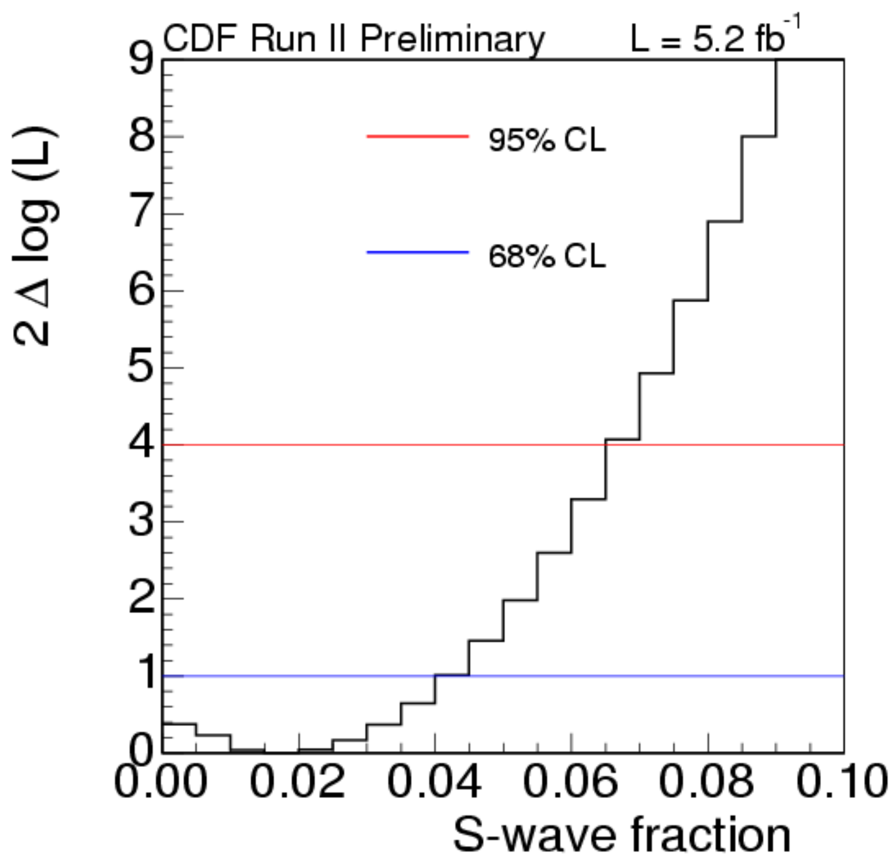


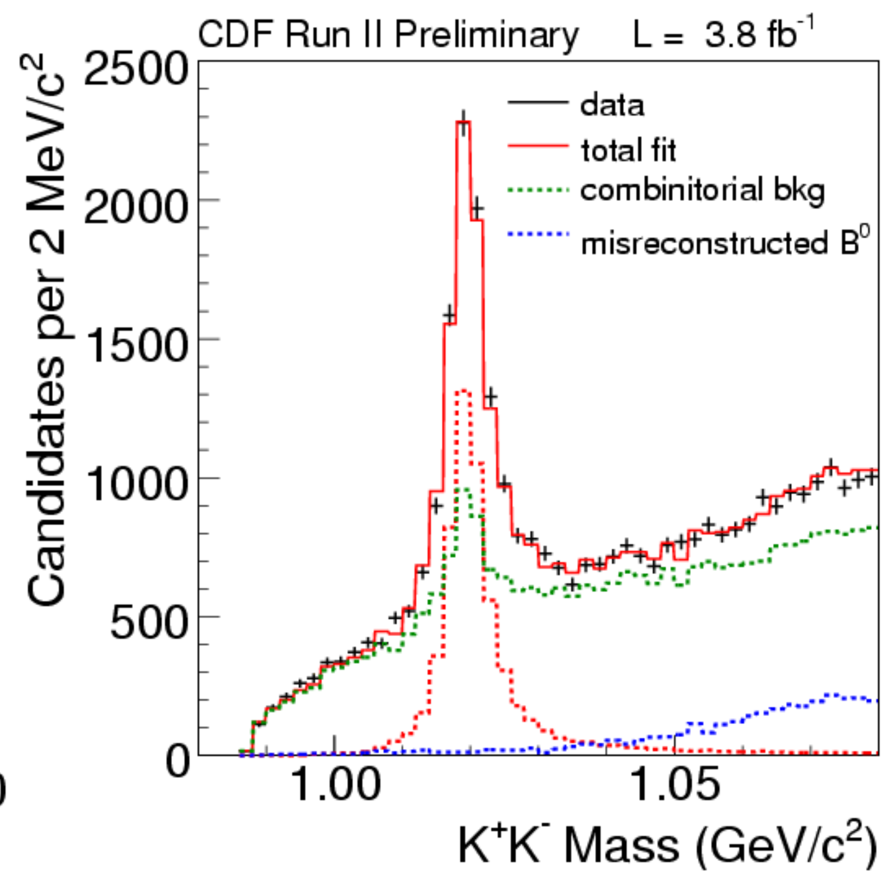
Obtain 0.8σ discrepancy w/SM prediction for β_s=0.02, $\Delta\Gamma$ = 0.096

Integrating over $\Delta\Gamma$ gives 1σ discrepancy with SM expectation that β_s=0.02

http://www-cdf.fnal.gov/physics/new/bottom/100513.blessed-BsJpsiPhi_5.2fb/

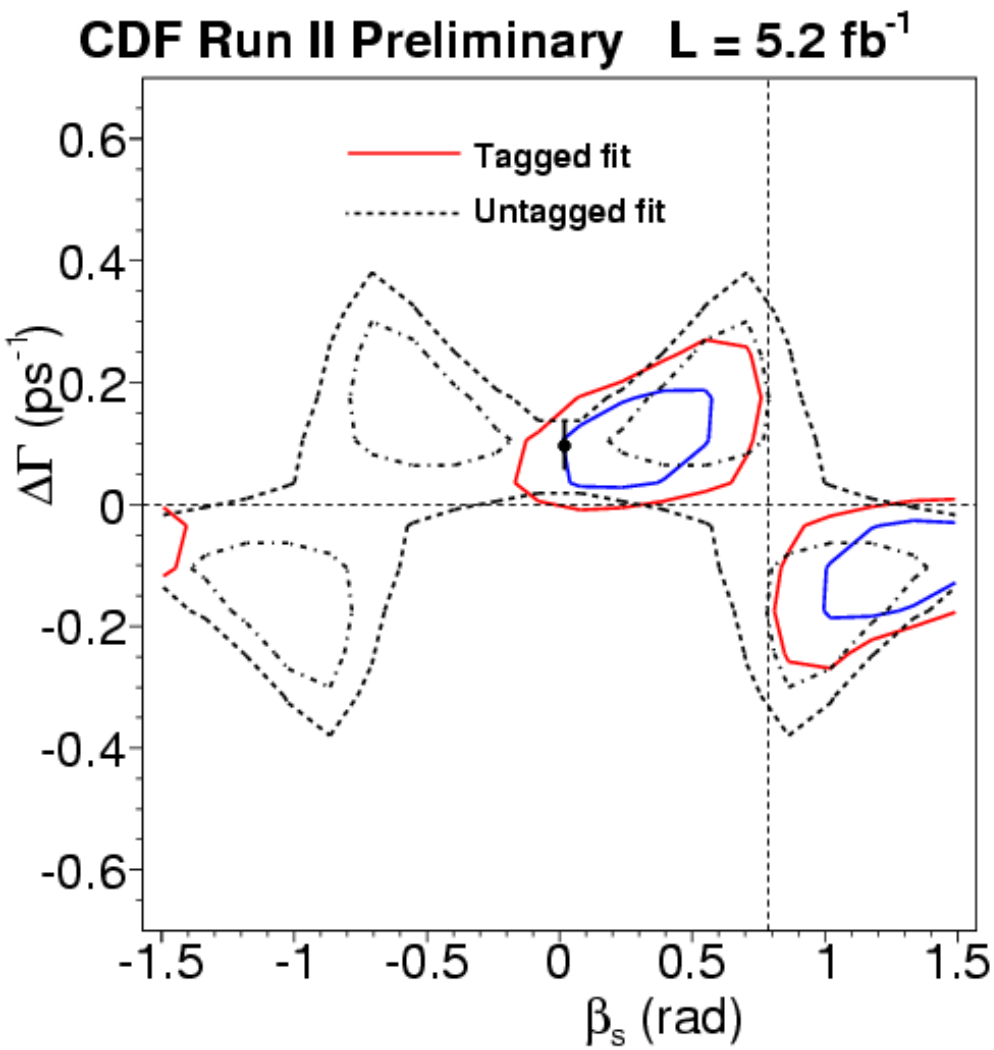
S-wave fraction consistent with zero





$f_{s\text{-}wave} \in [0, 6.7\%]$ at 95% CL

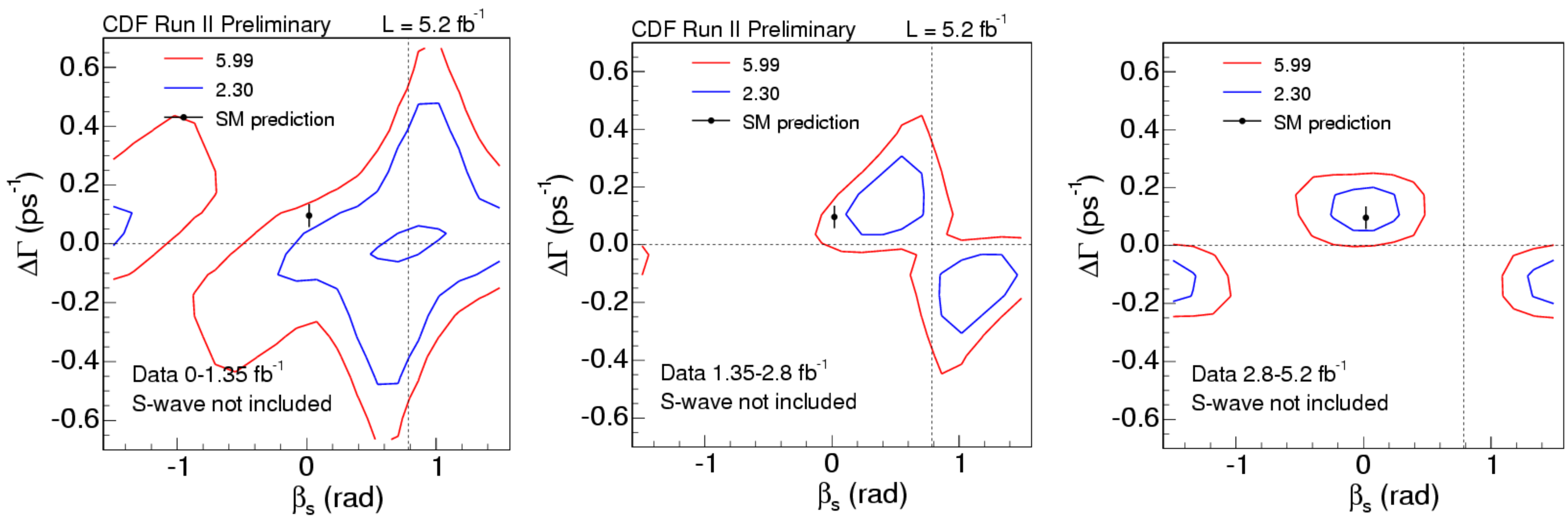
Check β_s–$\Delta\Gamma$ fit without flavor tagging



Untagged and tagged fits agree well.

Clearly demonstrates the two-fold reduction in solutions due to flavor-tagging…

Check fit in different data periods



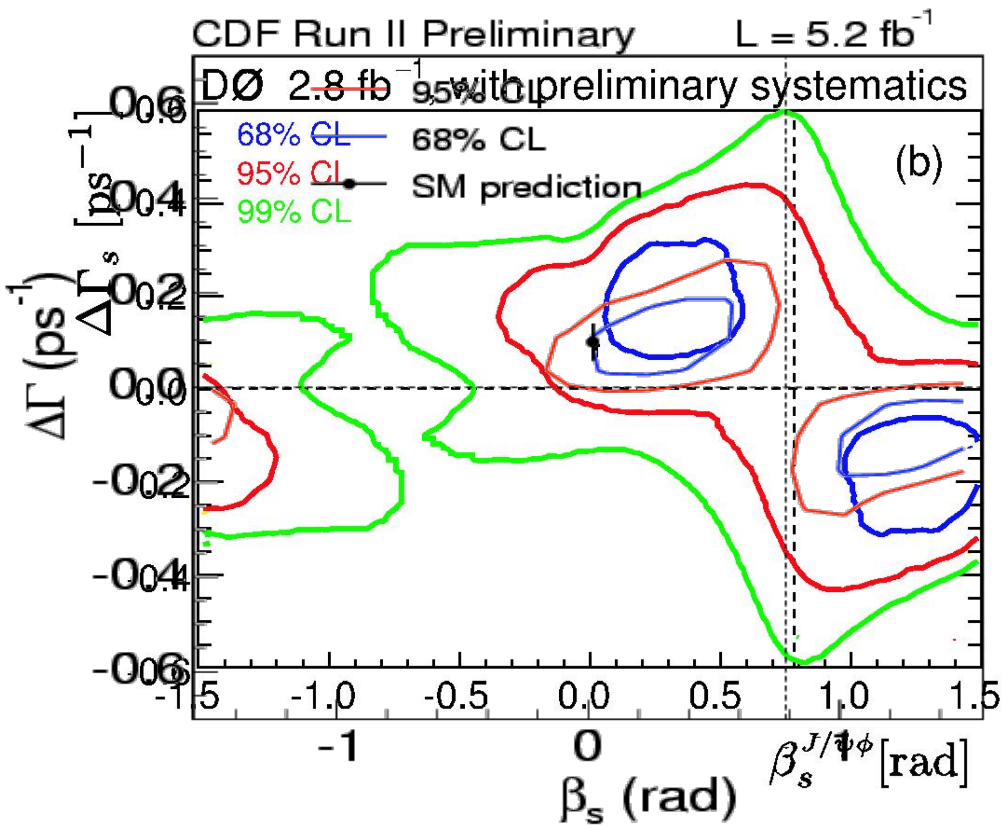
Fix β_s to SM expectation

Best measurement of B_s^0 lifetime, width difference, $B_s^0 \to J/\psi\varphi$ polarization amplitudes

$$\begin{aligned} c\tau(B_s^0) &= 458.6 \pm 7.5\ (\text{stat.}) \pm 3.6\ (\text{syst.})\ \mu\text{m} \\ \Delta\Gamma &= 0.075 \pm 0.035\ (\text{stat.}) \pm 0.010\ (\text{syst.})\ \text{ps}^{-1} \\ |A_\parallel(0)|^2 &= 0.231 \pm 0.014\ (\text{stat}) \pm 0.015\ (\text{syst.}) \\ |A_0(0)|^2 &= 0.524 \pm 0.013\ (\text{stat}) \pm 0.015\ (\text{syst.}) \\ \phi_\perp &= 2.95 \pm 0.64\ (\text{stat}) \pm 0.07\ (\text{syst.}). \end{aligned}$$

Result now more consistent with that observed by D0

- D0 result very similar to CDF's!
  - Even more so now…



http://www-d0.fnal.gov/Run2Physics/WWW/results/prelim/B/B59/

Stay tuned for future updates to indirect NP searches!

Hopefully we'll also have evidence for NP from direct searches at LHC shortly!!!

Back-up

Flavor physics program at Tevatron has been tremendously successful!

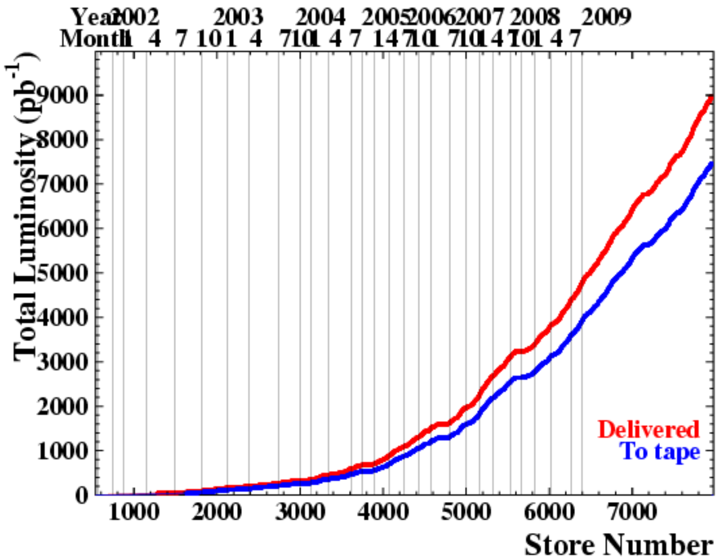
- Complements excellent programs of BABAR and Belle experiments at the B-factories
  - e^+e^- colliders produce B's at the $\Upsilon(4S)$ and $\Upsilon(5S)$
- Many unique measurements made at Tevatron
  - Observation of B_s mixing
  - CP violation in B_s systems
  - Discovery of b-baryons

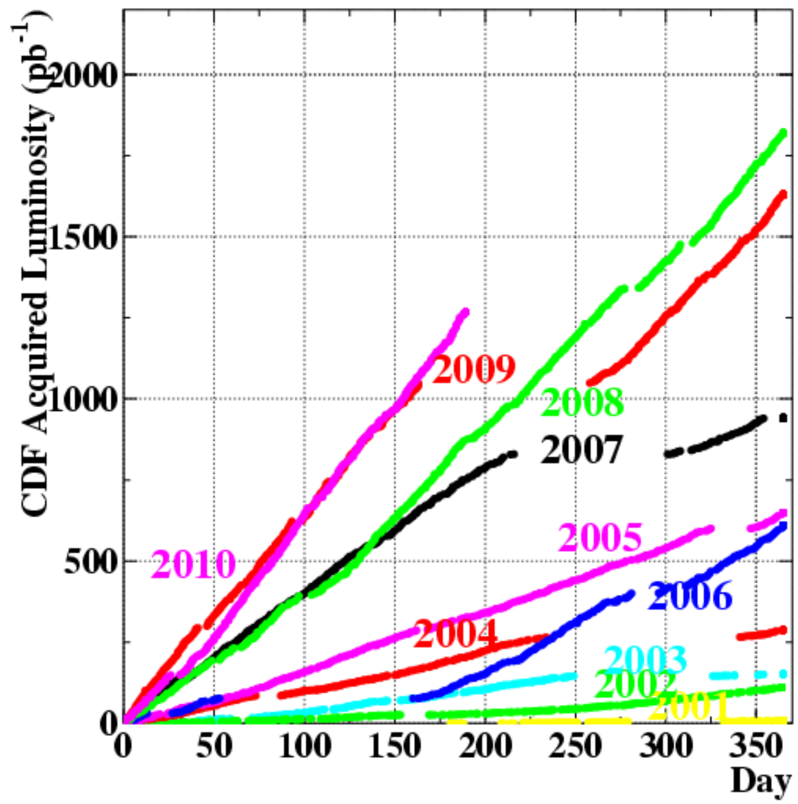
Everyone wants to find “New Physics”

- The search for physics beyond the standard model is pursued through a broad program in HEP and PA
  - Direct searches for evidence of SUSY, leptoquarks, gravitons, ???
  - Searches for dark matter/dark energy
  - Indirect NP searches
    - New physics in loop processes could contribute additional CP violating phases, enhance rare decay rates

Tevatron Performance Has Been Excellent!

- Delivered ~9 fb^{-1} of integrated luminosity
  - CDF and D0 experiments each have collected >7.4 fb^{-1}





Relative & absolute $b \to s\mu^+\mu^-$ branching ratios

Use $\mathcal{B}(B \to J/\psi h)$ to calculate absolute branching ratios

$$\mathcal{B}(B^+ \to K^+\mu^+\mu^-)/\mathcal{B}(B^+ \to J/\psi K^+) = [0.38 \pm 0.05(\mathrm{stat}) \pm 0.02(\mathrm{syst})] \times 10^{-3},$$
$$\mathcal{B}(B^0 \to K^{*0}\mu^+\mu^-)/\mathcal{B}(B^0 \to J/\psi K^{*0}) = [0.80 \pm 0.10(\mathrm{stat}) \pm 0.06(\mathrm{syst})] \times 10^{-3},$$
$$\mathcal{B}(B_s^0 \to \phi\mu^+\mu^-)/\mathcal{B}(B_s^0 \to J/\psi \phi) = [1.11 \pm 0.25(\mathrm{stat}) \pm 0.09(\mathrm{syst})] \times 10^{-3}.$$

$$\mathcal{B}(B^+ \to K^+\mu^+\mu^-) = [0.38 \pm 0.05(\mathrm{stat}) \pm 0.03(\mathrm{syst})] \times 10^{-6},$$
$$\mathcal{B}(B^0 \to K^{*0}\mu^+\mu^-) = [1.06 \pm 0.14(\mathrm{stat}) \pm 0.09(\mathrm{syst})] \times 10^{-6},$$
$$\mathcal{B}(B_s^0 \to \phi\mu^+\mu^-) = [1.44 \pm 0.33(\mathrm{stat}) \pm 0.46(\mathrm{syst})] \times 10^{-6}.$$

BRs from BELLE (PRL103, 171801)

$$\mathcal{B}(B \to K^*\ell^+\ell^-) = (10.7^{+1.1}_{-1.0} \pm 0.9) \times 10^{-7},$$
$$\mathcal{B}(B \to K\ell^+\ell^-) = (4.8^{+0.5}_{-0.4} \pm 0.3) \times 10^{-7};$$

Fit results for $B \rightarrow K^{(*)}\mu^+\mu^-$

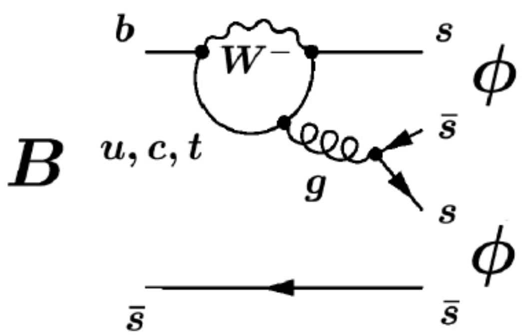
$B^0 \rightarrow K^{*0}\mu^+\mu^-$

q^2 (GeV^2/c^2)	N_{sig}	$\mathcal{B}(10^{-7})$	$\mathrm{F_L}$	$\mathrm{A_{FB}}$
0.00-2.00	8.52 ± 3.05	$0.98 \pm 0.40 \pm 0.09$	$0.53^{+0.32}_{-0.34} \pm 0.07$	$+0.13^{+1.65}_{-0.75} \pm 0.25$
2.00-4.30	8.91 ± 2.79	$1.00 \pm 0.38 \pm 0.09$	$0.40^{+0.32}_{-0.33} \pm 0.08$	$+0.19^{+0.40}_{-0.41} \pm 0.14$
4.30-8.68	16.86 ± 5.31	$1.69 \pm 0.57 \pm 0.15$	$0.82^{+0.19}_{-0.23} \pm 0.07$	$-0.06^{+0.30}_{-0.28} \pm 0.05$
10.09-12.86	25.71 ± 5.38	$1.97 \pm 0.47 \pm 0.17$	$0.31^{+0.19}_{-0.18} \pm 0.02$	$+0.66^{+0.23}_{-0.20} \pm 0.07$
14.18-16.00	21.91 ± 3.95	$1.51 \pm 0.36 \pm 0.13$	$0.55^{+0.17}_{-0.18} \pm 0.02$	$+0.42^{+0.16}_{-0.16} \pm 0.09$
16.00-19.30	19.78 ± 4.78	$1.35 \pm 0.37 \pm 0.12$	$0.09^{+0.18}_{-0.14} \pm 0.03$	$+0.70^{+0.16}_{-0.25} \pm 0.10$
0.00-4.30	17.43 ± 4.13	$1.98 \pm 0.55 \pm 0.18$	$0.47^{+0.23}_{-0.24} \pm 0.03$	$+0.21^{+0.31}_{-0.33} \pm 0.05$
1.00-6.00	13.92 ± 4.29	$1.60 \pm 0.54 \pm 0.14$	$0.50^{+0.27}_{-0.30} \pm 0.03$	$+0.43^{+0.36}_{-0.37} \pm 0.06$

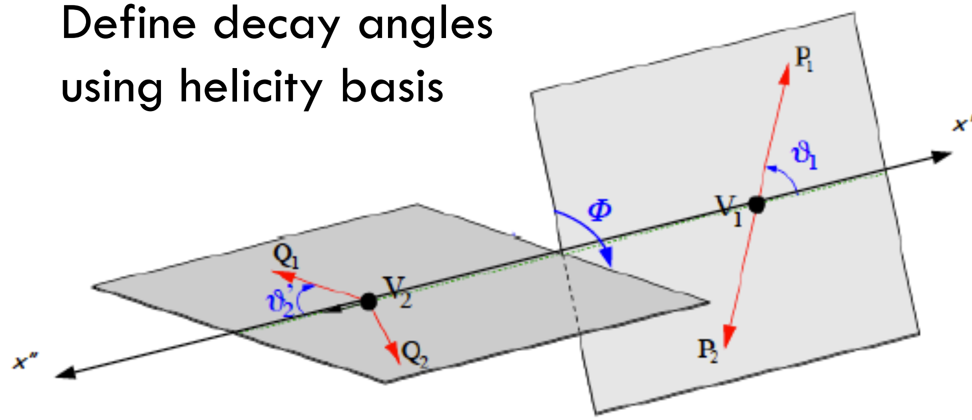
$B^+ \rightarrow K^+\mu^+\mu^-$

q^2 (GeV^2/c^2)	N_{sig}	$\mathcal{B}(10^{-7})$	$\mathrm{F_L}$	$\mathrm{A_{FB}}$
0.00-2.00	11.58 ± 4.60	$0.38 \pm 0.16 \pm 0.03$	-	$-0.15^{+0.46}_{-0.39} \pm 0.08$
2.00-4.30	18.02 ± 5.48	$0.58 \pm 0.19 \pm 0.04$	-	$+0.72^{+0.40}_{-0.35} \pm 0.07$
4.30-8.68	34.53 ± 8.87	$0.93 \pm 0.25 \pm 0.06$	-	$-0.20^{+0.17}_{-0.28} \pm 0.03$
10.09-12.86	29.15 ± 6.24	$0.72 \pm 0.17 \pm 0.05$	-	$-0.10^{+0.17}_{-0.15} \pm 0.07$
14.18-16.00	15.98 ± 4.64	$0.38 \pm 0.12 \pm 0.03$	-	$+0.03^{+0.49}_{-0.16} \pm 0.04$
16.00-23.00	13.94 ± 5.00	$0.35 \pm 0.13 \pm 0.02$	-	$+0.07^{+0.30}_{-0.23} \pm 0.02$
0.00-4.30	29.37 ± 7.15	$0.96 \pm 0.25 \pm 0.06$	-	$+0.36^{+0.24}_{-0.26} \pm 0.06$
1.00-6.00	32.67 ± 8.11	$1.01 \pm 0.26 \pm 0.07$	-	$+0.08^{+0.27}_{-0.22} \pm 0.07$

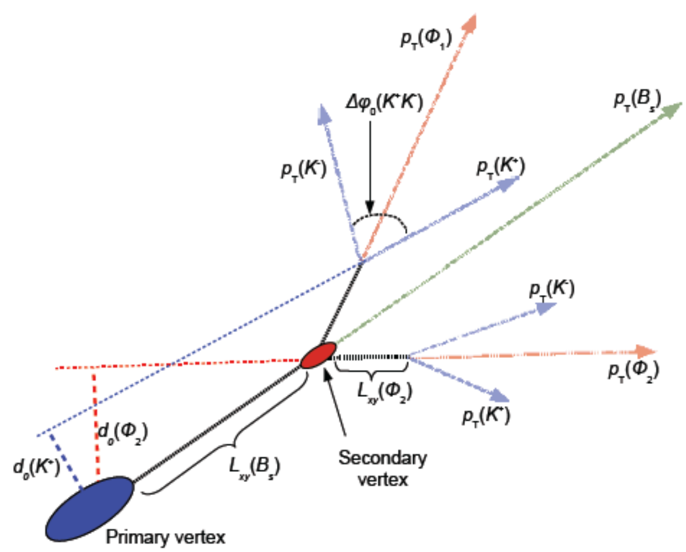
$B_s^0 \rightarrow \varphi\varphi$ polarization



Define decay angles using helicity basis



Use displaced track data set to reconstruct $B_s^0 \rightarrow \varphi\varphi$ signal



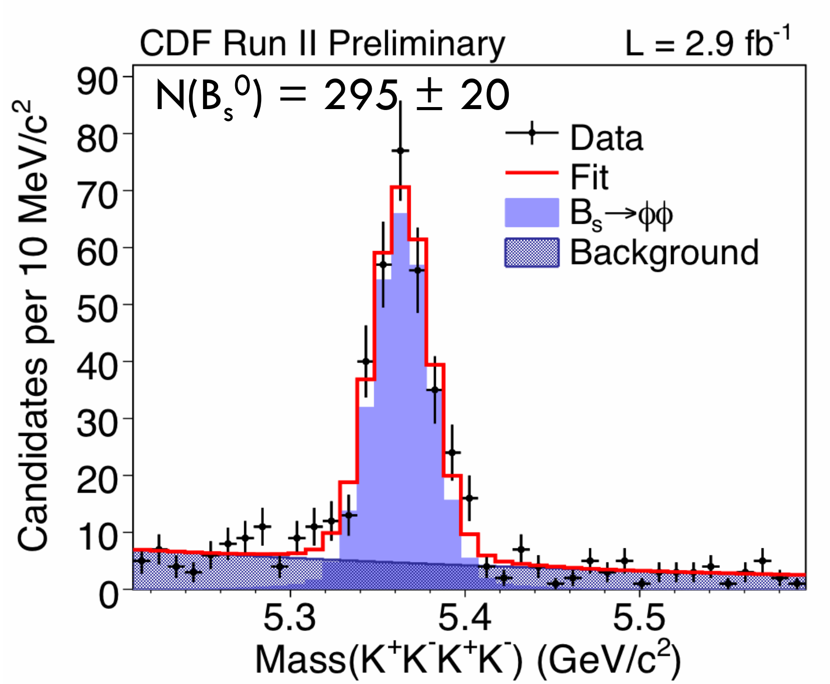
Fit for $B_s^0 \to \varphi\varphi$ polarization amplitudes

$$P_s(\vec{\omega}) = \frac{9}{16\pi} \frac{1}{\Gamma_H\left(|A_0|^2 + |A_\parallel|^2\right) + \Gamma_L |A_\perp|^2}$$

$$\times\left[\Gamma_H\left(|A_0|^2 f_1(\vec{\omega}) + |A_\parallel|^2 f_2(\vec{\omega}) + |A_0||A_\parallel|\cos\delta_\parallel f_5(\vec{\omega})\right) + \Gamma_L |A_\perp|^2 f_3(\vec{\omega})\right]$$

Since statistics are low, don't use time-dependent information (plus, trigger selection removes events that decay quickly $\Rightarrow$ need to understand efficiency.) Completely equivalent to simplest likelihood for $B_s^0 \to J/\psi\varphi$.

Fit for $B_s^0 \to \varphi\varphi$ polarization amplitudes



Fit for polarization amplitudes, strong phase $\delta_{||}$

$$|A_0|^2 = 0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst})$$
$$|A_\parallel|^2 = 0.287 \pm 0.043(\text{stat}) \pm 0.011(\text{syst})$$
$$|A_\perp|^2 = 0.365 \pm 0.044(\text{stat}) \pm 0.027(\text{syst})$$
$$\cos\delta_\parallel = -0.91^{+0.15}_{-0.13}(\text{stat}) \pm 0.09(\text{syst})$$

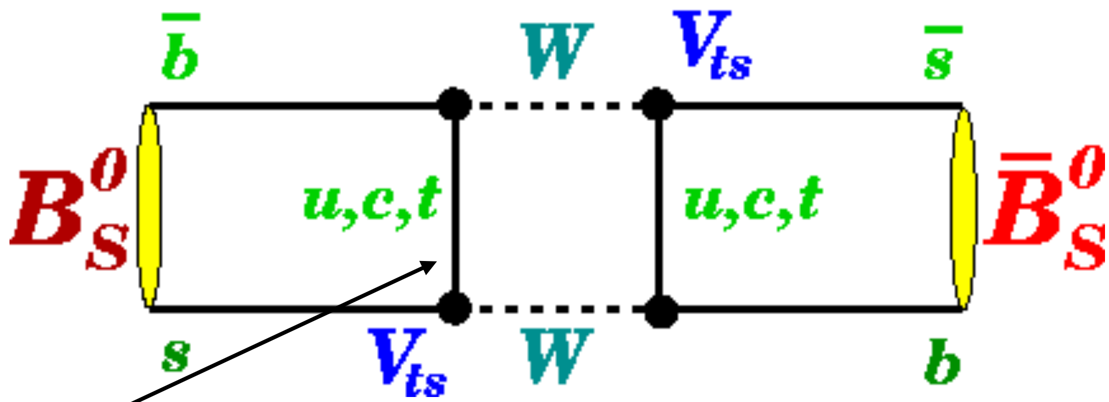
Longitudinal and transverse polarization fractions

$$f_L = 0.348 \pm 0.041(\text{stat}) \pm 0.021(\text{syst})$$
$$f_T = 0.652 \pm 0.041(\text{stat}) \pm 0.021(\text{syst})$$

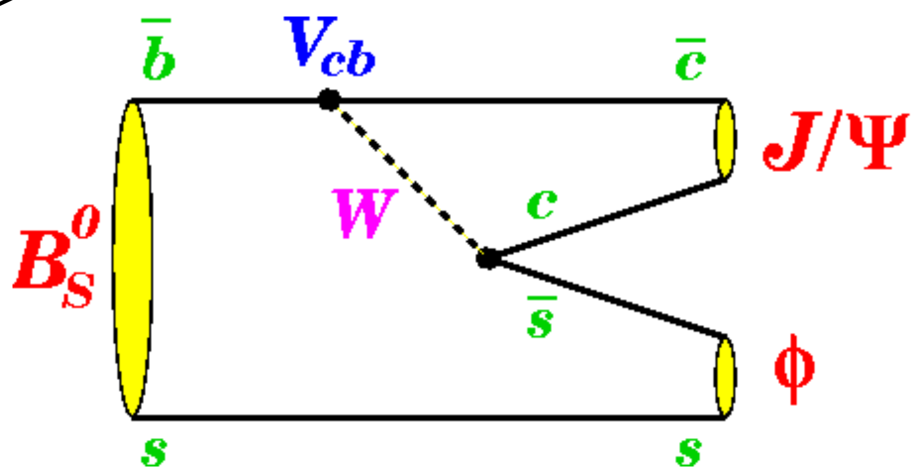
Mixing and decay in B_s^0

Mixing between particle and anti-particle occurs through the loop processes

Oscillations are very fast- ~3 trillion times per second!

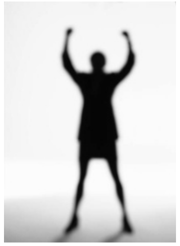


New particles can contribute to box diagram!



Three types of CP violation

- Decay of hadrons ↔ direct CPV
  - Only type of CPV for charged mesons



- Mixing of neutral mesons ↔ indirect CPV
  - Semi-leptonic decays of neutral meson

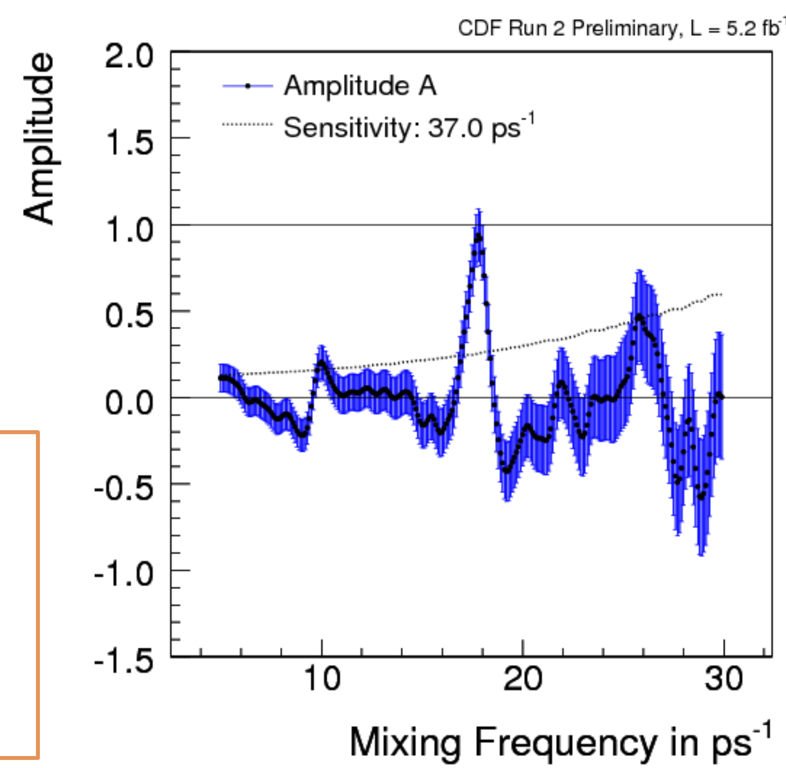
- Interference between decays with and without mixing
  - $B^0 \to J/\psi\, K_s^0 \Rightarrow \sin 2\beta$
  - $B_s^0 \to J/\psi\varphi \Rightarrow \sin 2\beta_s$

Measured precisely by BABAR and Belle

Use B_s^0 mixing to calibrate SSKT

$$P_s(t,\xi\,|\,\sigma_t,\mathcal{D}) = \frac{1}{N}\cdot\frac{1}{\tau}e^{-t/\tau}\left(1+\xi\mathcal{A}\mathcal{D}\cos\left(\Delta m_s t\right)\right)\otimes G(t\,|\,\sigma_t)\cdot\varepsilon(t\,|\,\sigma_t)$$

- Update mixing measurement to 5.2 fb^{-1} of data
  - $B_s^0 \rightarrow D_s^-[\rightarrow \varphi\pi^-]\pi^+$
  - $B_s^0 \rightarrow D_s^-[\rightarrow \varphi\pi^-]\pi^+\pi^+\pi^-$
  - $B_s^0 \rightarrow D_s^-[\rightarrow K^{*0}K^-]\pi^+$
  - $B_s^0 \rightarrow D_s^-[\rightarrow \pi^+\pi^-\pi^-]\pi^+$



$\mathcal{A}$ = 0.94 ±0.15 (stat) ±0.13 (syst)

$\varepsilon\mathcal{A}^2\mathcal{D}^2$ = 3.2 ±1.4%

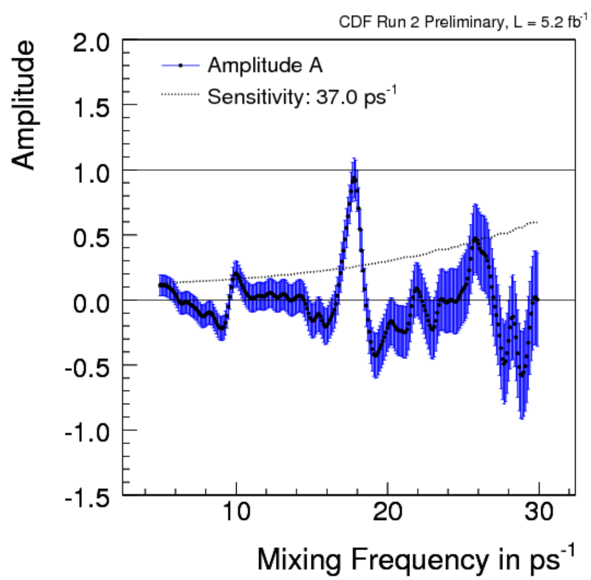
$c\tau$ = 451.2 ± 5.5 (stat.) μm

Δm_s = 17.79 ± 0.07 (stat.) ps^{-1}

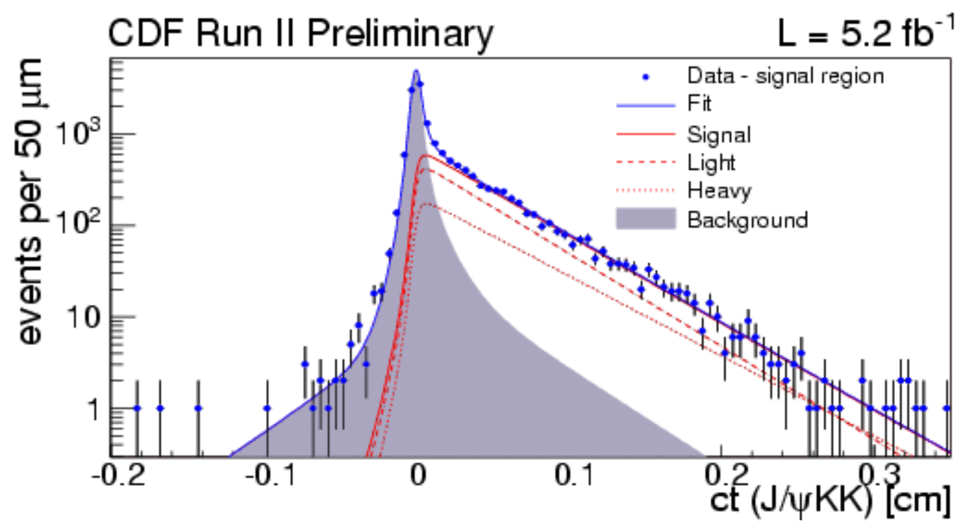
Mixing and decay in B_s^0

Mixing of B_s^0 mesons is governed by Schrodinger eqn.

$$\boxed{i\frac{d}{dt}\begin{pmatrix}|B_s^0(t)\rangle\\ |\bar{B}_s^0(t)\rangle\end{pmatrix} = \left(\mathbf{M}-\frac{i}{2}\mathbf{\Gamma}\right)\begin{pmatrix}|B_s^0(t)\rangle\\ |\bar{B}_s^0(t)\rangle\end{pmatrix}} \Longrightarrow \begin{array}{l}|B_s^H\rangle = p\,|B_s^0\rangle - q\,|\bar{B}_s^0\rangle\\ |B_s^L\rangle = p\,|B_s^0\rangle + q\,|\bar{B}_s^0\rangle\end{array}$$



$\Delta m_s = m_H - m_L$



$\Delta\Gamma_s = \Gamma_L - \Gamma_H$

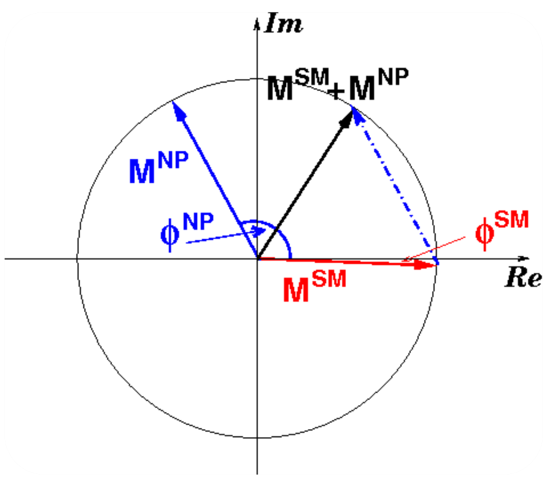
http://www-cdf.fnal.gov/physics/new/bottom/100204.blessed-sskt-calibration/index.html

$B_s^0 \rightarrow J/\psi\varphi$ Decays Are A Good Place to Look for New Physics

- Decays of $B_s^0 \rightarrow J/\psi\varphi$ gives access to CP violating phase predicted to be nearly zero in Standard Model

$$\beta_s^{J/\psi\varphi} = \arg\left(-\frac{V_{ts}V_{tb}^*}{V_{cs}V_{cb}^*} \right) \sim 0.02$$

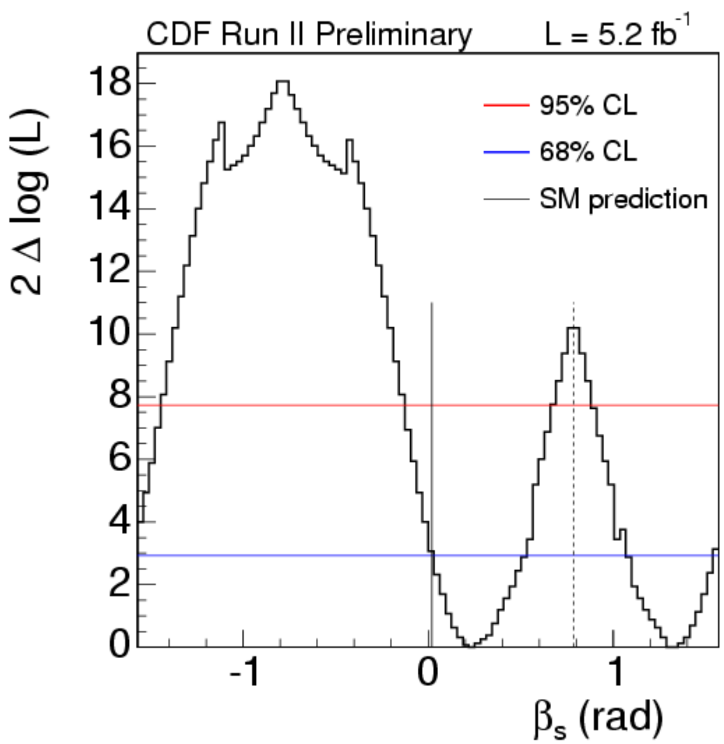
- Large phase in $b \rightarrow s$ transition could lead to significant non-zero CP phase



New physics could produce large CP phase!

G. Hou et al suggest that t' quark w/mass ~300 GeV/c^2 – 1 TeV/c^2 would give β_s~0.5

1D β_s result



1σ discrepancy with SM prediction

[0.02,0.52] U [1.08,1.55] @ 68% CL

[-π/2, -1.44] U [-0.13, 0.68] U [0.89, π/2] @ 95% CL